Resuscitation Plus 1-2 (2020) 100004

Contents lists available at ScienceDirect

Resuscitation Plus

journal homepage: www.journals.elsevier.com/resuscitation-plus

Review

Anticipatory manual defibrillator charging during advanced life support: A scoping review

Quentin Otto [a,b,*], Szymon Musiol [a], Charles D. Deakin [c], Peter Morley [d,e], Jasmeet Soar [b]

[a] *Severn Deanery, Bristol, UK*
[b] *Intensive Care Unit, North Bristol NHS Trust, Bristol, UK*
[c] *University Hospital Southampton NHS Foundation Trust, Southampton, UK*
[d] *The Royal Melbourne Hospital, Victoria, Australia*
[e] *The University of Melbourne, Victoria, Australia*

ARTICLE INFO

Keywords:
Cardiac arrest
Heart arrest
Defibrillation
Advanced life support
Cardiopulmonary resuscitation
Manual defibrillator

ABSTRACT

Background: Some resuscitation services advocate or teach routine manual defibrillator charging prior to a rhythm check during cardiopulmonary resuscitation.

Objectives: We aimed to review the evidence for anticipatory defibrillator charging compared with charging after a shockable rhythm is confirmed.

Methods: This scoping review was performed according to a specific methodological framework and the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews. Grey literature was also reviewed using similar methodology and included in the results.

Results: There are no randomized clinical trials studying anticipatory manual defibrillator charging. The limited available data does not address critical or important patient outcomes such as defibrillation success, return of spontaneous circulation, survival to hospital discharge or neurological outcomes. Evidence primarily from manikin studies and the grey literature suggests that anticipatory charging is feasible, safe, and can reduce the total pause duration during the period of chest compression between rhythm checks, but can increase the pre-shock pause and total peri-shock pause duration.

Conclusions: Anticipatory manual defibrillator charging appears to be feasible in the clinical setting, although its impact on clinical outcomes is uncertain. Future studies of anticipatory charging should focus on clinical outcomes.

Introduction

Rationale

Some national and regional resuscitation services have adopted a method of manual defibrillation during advanced life support (ALS) where the defibrillator is charged during chest compressions prior to a pause in chest compressions to identify the cardiac rhythm (in anticipation of a shockable rhythm). The patient is then immediately given a defibrillation shock or the defibrillator is disarmed, depending on whether a shockable heart rhythm is identified (Fig. 1A) before chest compressions resume.

We were not aware of evidence supporting this anticipatory charging over the current standard approach, as described by the American Heart Association (AHA) and European Resuscitation Council (ERC).[1–4]

The current standard approach recommends a pause in chest compressions to identify the cardiac rhythm, followed by further chest compressions whilst charging the defibrillator (if appropriate) and then a further pause in chest compressions while the shock is delivered (Fig. 1B).

Prior to guideline changes (AHA in 2005, ERC in 2010) chest compressions were not routinely provided during defibrillator charging (Fig. 1C).

Objectives

We aimed to review the evidence for anticipatory defibrillator charging compared with charging after a shockable rhythm is confirmed. The scoping review methodology was chosen given the apparent sparsity of evidence. If, following this scoping review, the International Liaison Committee on Resuscitation (ILCOR) Advanced Life Support (ALS) Task

* Corresponding author.
E-mail address: q.otto@nhs.net (Q. Otto).

https://doi.org/10.1016/j.resplu.2020.100004
Received 23 February 2020; Received in revised form 18 April 2020; Accepted 27 April 2020

Abbreviations

ALS	Adult Life Support
CPR	Cardiopulmonary resuscitation
AED	Automated external defibrillator
ROSC	Return of spontaneous circulation
pVT	Pulseless ventricular tachycardia
VF	Ventricular fibrillation
PEA	Pulseless electrical activity
ILCOR	International Liaison Committee on Resuscitation
AHA	American Heart Association
ERC	European Resuscitation Council

Force considered there was sufficient published data on this topic, this review would progress to a formal systematic review and if appropriate a meta-analysis to estimate the effect size of the intervention. In addition, we aimed to identify potential areas for future research.

This work was undertaken as part of the ILCOR ALS Task Force evidence evaluation process.[5]

The following population, interventions, comparators and outcomes were decided *a priori:*

Population: Adults with cardiac arrest in any setting.

Intervention: Charging the defibrillator prior to rhythm analysis during manual defibrillation.

Comparator: Charging the defibrillator after rhythm analysis during manual defibrillation.

Outcomes: Given the broad remit of a scoping review we considered any clinical outcome.

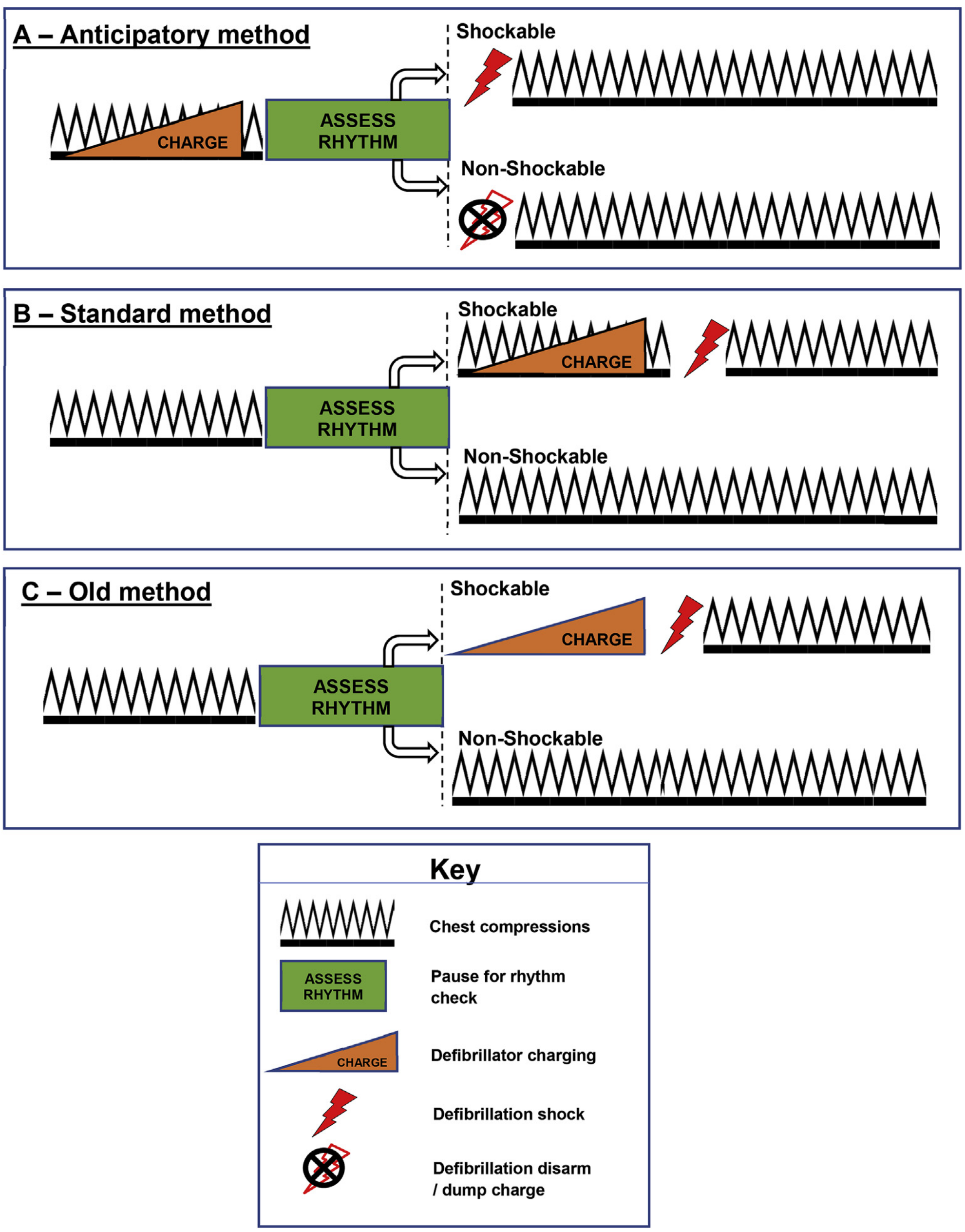

Fig. 1. Defibrillation methods **A**: Anticipatory method – charge during chest compressions prior to rhythm check. Disarm defibrillator or dump charge if non-shockable rhythm **B:** Standard Method – ERC and AHA guidelines (2010 and 2015). Pause for rhythm check, chest compressions during charging. **C:** Old Method - pause for rhythm check, no chest compressions during charging.

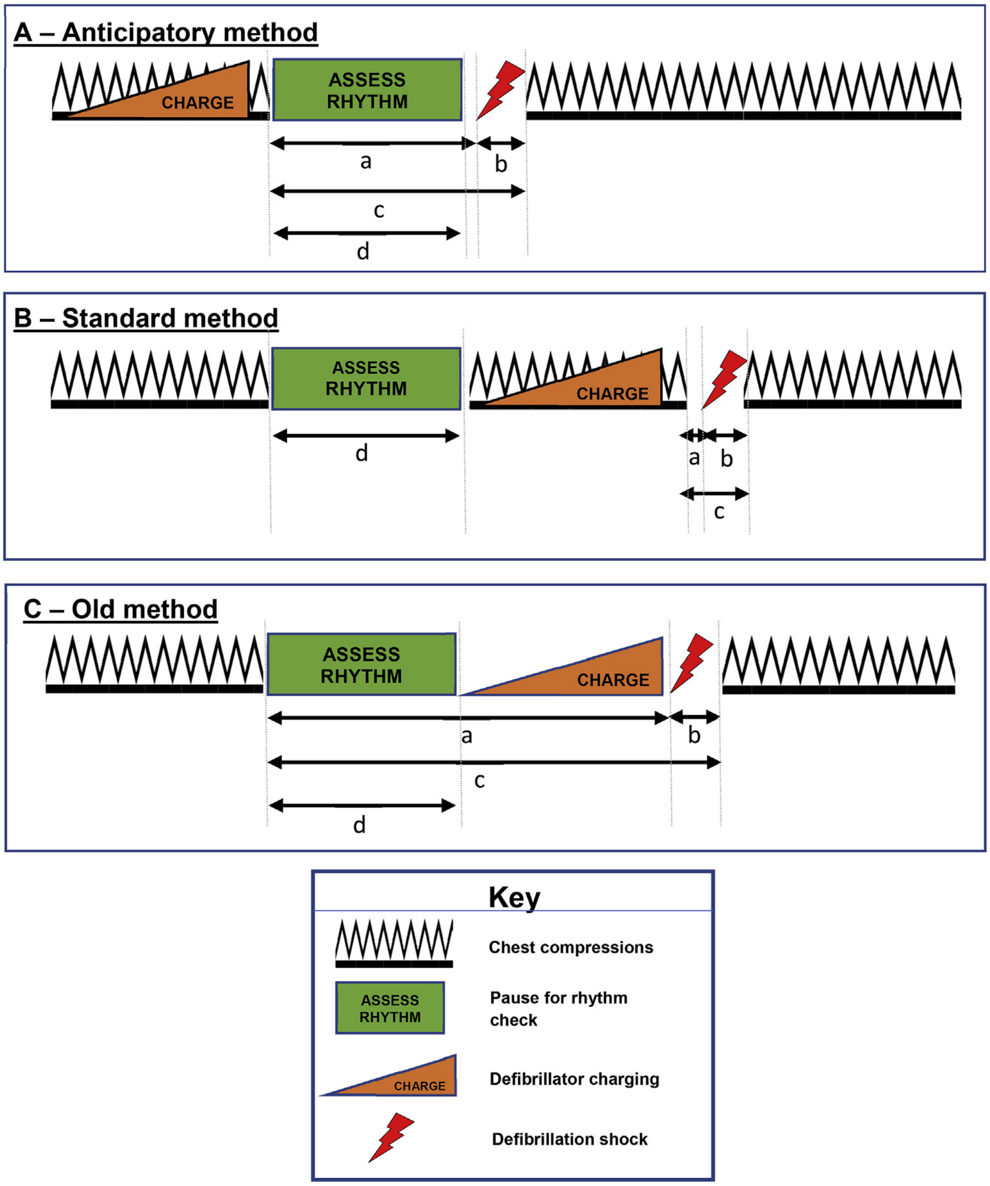

Fig. 2. Pauses during different defibrillation methods. **A:** Anticipatory method.. **B:** Standard method. **C:** Old Method **a:** Pre-shock pause. **b:** Post-shock pause **c:** Peri-shock pause (a+b) **d:** Rhythm check pause.

The ILCOR ALS Task Force ranked *a priori* critical outcomes as survival with favourable neurological outcome at discharge or 30 days or greater and survival to discharge or 30 days or greater. Return of spontaneous circulation (ROSC) was ranked as an important outcome. These outcomes are in accordance with the ILCOR Core Outcome Set for Cardiac Arrest (COSCA) in Adults.[6,7]

Other relevant outcomes of interest that were identified included defibrillation success, pre-shock pause, post-shock pause, peri-shock pause, hands-off time, hands-on time, compression fraction, inappropriate shocks, shocks during chest compression (shock to rescuer) and any other defibrillation measure.

Methods

Protocol

A specific review protocol for this scoping review was agreed and approved beforehand according to the International Liaison Committee on Resuscitation (ILCOR) Task Force Scoping Reviews (TFScR) Guidance v 1.0[5] on 29 Sept 2019.

This review follows a recommended methodological framework[9] and the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR).[8]

Eligibility criteria

Study Designs: Human and manikin studies included. Randomized controlled trials (RCTs) and non-randomized studies (non-randomized controlled trials, interrupted time series, and controlled before-and-after studies, cohort studies) were eligible for inclusion. Unpublished studies were excluded, but any relevant grey literature was noted for discussion. Grey literature includes resources that were not produced for peer-reviewed academic publication (e.g. documents, guidelines, training manuals, abstracts, conference posters.[11–13])

Timeframe and languages: All years and all languages included. Studies without a title in English were excluded.

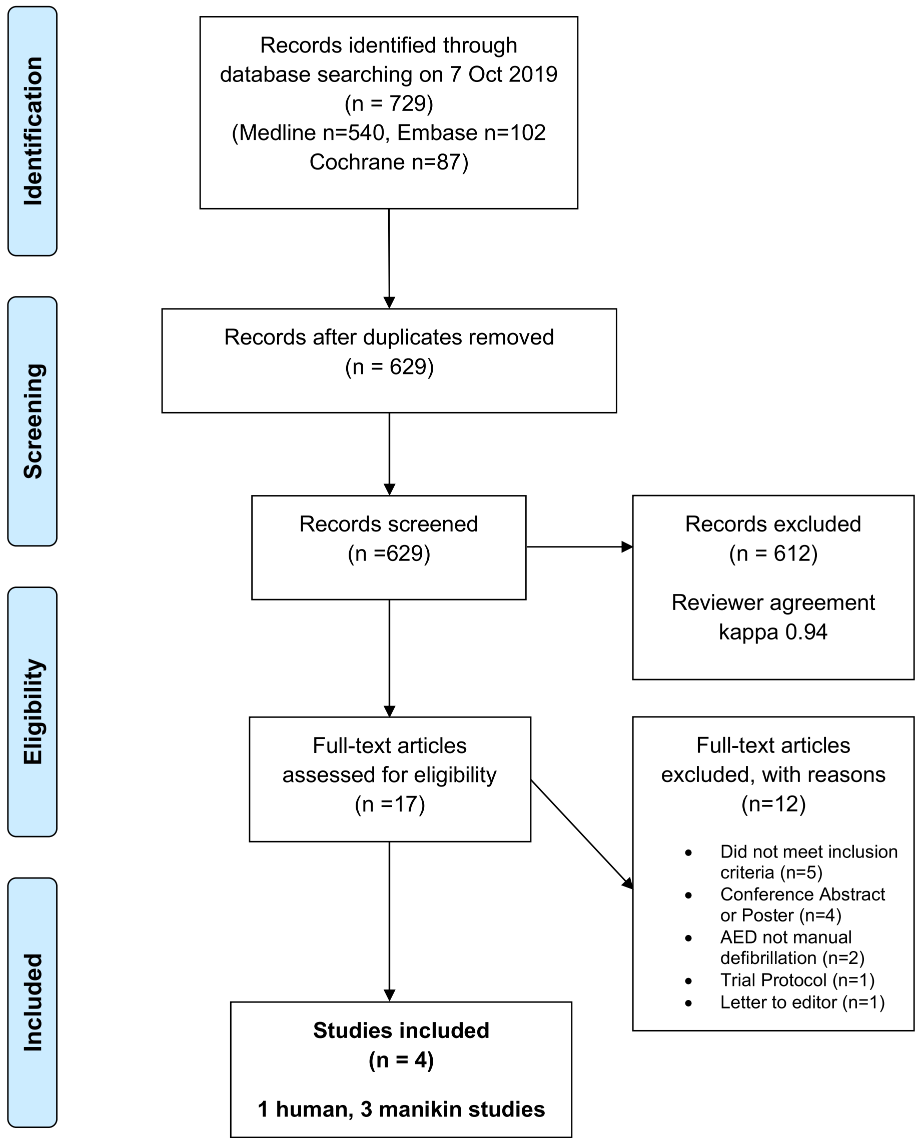

Fig. 3. PRISMA flow diagram.

Information sources

Email correspondence (2015–2019) between members of the International Liaison Committee on Resuscitation Task Force groups and responses from representatives from national resuscitation councils identified that there is widespread adoption and teaching of the anticipatory charging method in (but not limited to) Australia, New Zealand, the Netherlands and parts of the USA. Training manuals and course algorithms were also reviewed from different Australian resuscitation services.

A formal literature search strategy was developed and a search completed using HDAS (Healthcare Databases Advanced Search).[10] The databases searched were EMBASE (1974 to present), MEDLINE (1946 to present) and Cochrane, on 7 October 2019. The full search strategy is presented in supplementary Appendix A1.

Selection of sources of evidence

The search results were screened independently using title and abstract for relevance to the PICOST by two individuals (QO and SM). Included studies were put forward for full paper analysis. There was good reviewer agreement (kappa 0.94). A third reviewer (JS) reviewed the papers where there was disagreement regarding inclusion. Review of full texts and data abstraction was completed by three reviewers (QO, SM and JS).

Some relevant but excluded studies and results from the grey literature were also reviewed and are included in supplementary Appendix A2.

The inclusion of grey literature in the qualitative review and narrative discussion of this topic was undertaken due to the limited body of published evidence relating to the subject and the importance of assessing a broad range of sources as part of the scoping review process.[11–13]

Data charting process

Data was charted using the format outlined in the International Liaison Committee on Resuscitation (ILCOR) Task Force Scoping Reviews (TFScR) Guidance v 1.0.[5] Data were charted collaboratively by two reviewers (QO and SM) and iteratively discussed and updated. The data were ratified by a third reviewer (JS).

Data items

We abstracted data on article characteristics (date, location), methods, population of both practitioners/providers and recipients,

Table 1
Characteristics of sources of evidence.

Reference	Method	Setting	Population	Outcomes reported
Edelson, 2010[14]	Multi-centre retrospective study HUMAN	Three teaching hospitals, United States	680 charge cycles from 244 in-hospital cardiac arrests involving 225 distinct patients April 2006 to April 2009	Pre-shock pause Post-shock pause Total hands-off time in 30 s preceding shock Inappropriate shocks Shocks to rescuers
Hansen, 2013[15]	Single-centre Randomized crossover study MANIKIN	Regional hospital, Denmark	Volunteer junior physicians confronted with simulated adult cardiac arrest, randomly assigned arrest rhythm of both pulseless VT (pVT) and asystole (AS). 10 physicians for comparison with ERC 2005 and 12 for ERC 2010	Hands-off time
Kemper, 2019[16]	Single-centre randomized controlled study. MANIKIN	Unclear, Germany	243 Medical Students presented with randomly sequenced pulseless VT (pVT), VF or asystole (AS)	No flow time Peri-shock pause Pre-shock pause Post-shock pause Number of peri-shock pauses longer than 5s Total pause
Koch Hansen, 2016[17]	Single-centre randomized crossover study MANIKIN	University hospital, Denmark	29 Volunteer cardiology physicians randomly assigned roles in an arrest team and confronted randomly with different arrest rhythms (pVT, VF, PEA, AS) in 11 simulated adult cardiac arrest scenarios. Oral command for control or intervention algorithm.	Hands-off time percentage

interventions, comparisons and outcomes of included studies.

Pause times were defined as follows (Fig. 2):

- Pre-shock pause– time from cessation of chest compression to shock delivery.
- Post-shock pause – time from shock delivery to commencement of chest compression.
- Peri-shock pause – the total pause in chest compression either side of shock delivery (sum of pre-shock and post-shock pause).
- Rhythm check pause – the time taken to diagnose the cardiac arrest rhythm and any associated clinical assessment (e.g. pulse check). Depending on the algorithm used this may be a distinct pause or a constituent of the pre-shock pause.
- Total hands-off time – the sum of all pauses in chest compression per cycle of CPR.

Any data relating to defibrillation safety were also charted.

Further excluded but relevant grey literature was included in a separate table for discussion, using the same methodology and charting process (Supplementary Appendix A2, Table A1).

Synthesis of results

Included articles were grouped by study type into human and mannikin studies. The studies were summarised by two reviewers (QO and SM) to outline the key outcomes that were identified, along with any safety data and the limitations of the studies. Narrative conclusions were drawn for each study. The synthesis was edited by a third reviewer (JS).

Results

The results of the search and selection of sources of evidence are summarised in the PRISMA flow diagram (Fig. 3). Characteristics and results of sources of evidence are summarised in Tables 1 and 2.

In the only human study,[14] anticipatory charging led to a shorter total hands-off time in the 30 s preceding the shock. No clinical outcome measures were reported. One rescuer was accidently shocked with the anticipatory method. The manikin studies report discrepant results. In Hansen et al.[15] anticipatory charging led to an overall reduction in hands-off time, the result being mainly driven by the shockable side of the algorithm. In Koch Hansen et al.[17] the mean hands-off time was also lower in the anticipatory charging group (referred to in this study as Stop-Only-While-Shocking). In Kemper et al.[16] the anticipatory method led to longer peri-shock, pre-shock and post-shock pauses, as well as a larger number of peri-shock pauses exceeding 5 s, but shorter total pause time. In terms of safety, there was no difference in inappropriate shocks between anticipatory charging and the standard method in the patient study. In addition, this study found no differences in seventeen *defibrillation safety items*, apart from a *warning before defibrillation* being issued less reliably in the anticipatory method ($p = 0.026$). The key results are summarised in Table 3.

Discussion

Summary of evidence

We identified no randomized controlled clinical trials in humans addressing this topic.

The single human observational study[14] was not designed to answer this question, did not report any critical or important outcomes (survival, neurological outcome, ROSC), and the relevant data for this review came from a subgroup analysis. In addition, no reason for the subgroup using an anticipatory charging method is given.

The human[14] and manikin studies[15–17] suggest that charging the defibrillator in anticipation of the rhythm check, and shocking or disarming as appropriate, increases the pre-shock pause and the peri-shock pause, but decreases the total number of pauses and hands-off time (Fig. 2).

We do not know the relative contribution of each of these pauses to critical and important outcomes. However, peri-shock pause is an important metric associated with key outcomes during resuscitation. Longer pauses worsen outcomes[18,19] and a shorter pre-shock pause is associated with increased defibrillation success.[20] Direct comparison of peri and pre-shock pauses between different defibrillation methods, however, is difficult and may not be valid as the nature of different

Table 2
Results of individual sources of evidence.

<table>
<tr><th>Reference</th><th>Intervention</th><th>Comparison</th><th>Outcomes</th></tr>
<tr><td>Edelson, 2010 [14]</td><td>Charging defibrillator prior to rhythm analysis
[If VF/pVT give shock]

[Anticipatory method]
n = 67 shocks</td><td>Charging defibrillator after rhythm assessment with ongoing chest compressions
[AHA method]
n = 255</td><td>Results from anticipatory subgroup analysis.
<table>
<tr><th></th><th>Anticipatory method</th><th>AHA method</th><th>p-value</th></tr>
<tr><td>**Pre-shock pause, median (IQR), s**</td><td>3.8 (2.4-5.4)</td><td>2.5 (1.8-3.3)</td><td>0.08</td></tr>
<tr><td>**Post-shock pause, median (IQR), s**</td><td>2.2 (1.6-3.5)</td><td>1.7 (1.3-2.5)</td><td>0.39</td></tr>
<tr><td>**Hand-off time in 30 s preceding shock**</td><td>3.9 (2.4-5.6)</td><td>11.5 (9.1-14.5)</td><td><0.001</td></tr>
<tr><td>**Inappropriate shocks, n/total (%)**</td><td>13/67 (19.4)</td><td>45/255 (17.6)</td><td>0.74</td></tr>
<tr><td>**Shocks to rescuers, n/total (%)**</td><td>1/67 (1.5)</td><td>0/255 (0.0)</td><td>0.05</td></tr>
</table></td></tr>
<tr><td>Hansen, 2013 [15]</td><td>Charging the defibrillator while ongoing compressions, then pausing for rhythm check and shocking if indicated (pVT) or disarming if not (AS).</td><td>ERC 2010 guideline algorithm, pausing for rhythm check, if pVT - compressions during charging and pause for shock before continuation of compressions</td><td>Results from ERC 2010 subgroup analysis. Reported as mean (95% CI)
<table>
<tr><th></th><th>Alternative sequence</th><th>ERC 2010</th><th>p-value</th></tr>
<tr><td>**Hands-off time (overall), s**</td><td>3.9 (3.4 - 4.4)</td><td>5.6 (4.5 – 6.8)</td><td>< 0.01</td></tr>
<tr><td>**Hands-off time (pVT scenarios), s**</td><td>4.5 (3.7 – 5.3)</td><td>7.6 (6.0 – 9.3)</td><td>< 0.01</td></tr>
<tr><td>**Hands-off time (asystole scenarios), s**</td><td>Not reported numerically</td><td>Not reported numerically</td><td>ns</td></tr>
</table></td></tr>
<tr><td>Kemper, 2019 [16]</td><td>Anticipatory defibrillator charging (ADC)

n = 75</td><td>ERC 2010 guideline algorithm (ERC), pausing for rhythm check, if VF or pVT - compressions during charging and pause for shock before continuation of compressions

n = 128</td><td>Results reported as mean (SD)
<table>
<tr><th></th><th>Anticipatory method</th><th>ERC 2010</th><th>p-value</th></tr>
<tr><td>**No-flow time, s**</td><td>25.8 (7.4)</td><td>27.4 (8.4)</td><td>0.19</td></tr>
<tr><td>**Peri-shock pause, s**</td><td>9.5 (2.8)</td><td>3.3 (1.9)</td><td><0.001</td></tr>
<tr><td>**Pre-shock pause, s**</td><td>6.9 (2.8)</td><td>1.6 (1.3)</td><td><0.001</td></tr>
<tr><td>**Post-shock pause, s**</td><td>2.6 (0.9)</td><td>1.7 (1)</td><td><0.001</td></tr>
<tr><td>**Total pause, s**</td><td>9.5 (2.8)</td><td>10.9 (3.3)</td><td>0.03</td></tr>
<tr><td>**Number of peri-shock pauses >5s**</td><td>1.8 (0.5)</td><td>0.2 (0.5)</td><td><0.001</td></tr>
</table></td></tr>
<tr><td>Koch Hansen, 2016 [17]</td><td>Stop-Only-While-Shocking (SOWS) - charging the defibrillator before rhythm check, while ongoing chest compressions</td><td>ERC 2010 guideline algorithm (ERC), pausing for rhythm check, if VF or pVT - compressions during charging and pause for shock before continuation of compressions</td><td>Reported as percentage of entire simulation (SD)
<table>
<tr><th></th><th>SOWS</th><th>ERC 2010</th><th>p-value</th></tr>
<tr><td>**Mean hands-off time (%)**</td><td>22.1 (2.3)</td><td>26.6 (4.8)</td><td>0.04</td></tr>
</table></td></tr>
</table>

pauses changes with the different defibrillation sequence used (Fig. 2). Little has been reported on post-shock pauses, but one manikin study showed that the post-shock pause time is longer with anticipatory charging.[16]

The available evidence provides very limited information about the relative safety of the two defibrillation strategies. We note that in the one human study,[14] a single rescuer received an accidental shock in the anticipatory shock group, but continued to provide compressions. There

Table 3

Synthesis of results. *p<0.05

	Pre-shock Pause (s)		Post Shock Pause (s)		Peri-shock Pause (s)		Hands-off time/ Total pause (s, unless stated)	
	Standard	Anticipatory	Standard	Anticipatory	Standard	Anticipatory	Standard	Anticipatory
Edelson 2010 [14] **(median IQR)**	2.5 (1.8-3.3)	3.8 (2.4-5.4)	1.7 (1.3-2.5)	2.2 (1.6-3.5)			11.5* (9.1-14.5)	3.9* (2.4-5.6)
							s, in 30 seconds prior to shock	
Hansen 2013 [15] **(mean, 95% CI)**							5.6* (4.5 -6.8)	3.9* (3.4-4.4)
Kemper 2019 [16] **(mean, SD)**	1.6* (1.3)	6.9* (2.8)	1.7* (1.0)	2.6* (0.9)	3.3* (1.9)	9.5* (2.8)	10.9* (3.3)	9.5* (2.8)
Koch Hansen 2016 [17] **(mean, SD)**							26.6* (4.8)	22.1* (2.3)
							% hands off time entire simulation	

was no evidence of harm to patient or rescuer in the included studies.

These two defibrillation strategies are primarily for a pads-based approach for manual defibrillation, which is the technique recommended by the ERC and the predominant method used in organised resuscitation systems other than for the management of burns patients (where burns may preclude the use of self-adhesive pads). Hansen[15] compared a study group using paddles, which showed similar differences for defibrillator pre-charging to that documented with adhesive pads.

We have also reviewed abstracts, posters, letters and related publications but these do not provide any new information. A summary table is outlined in supplementary Appendix A2, Table A1.

The consensus of the ILCOR ALS Task Force was that there were insufficient studies in terms of quality, homogeneity and quantity to support progressing to a systematic review on this topic.

It appears feasible to charge the defibrillator in anticipation of a rhythm check in and out of hospital, and cognitive aids have been used successfully in resuscitation systems to achieve this.[21,22] One such cognitive aid which has not been formally evaluated or endorsed by ILCOR is the 'C.O.A.C.H.E.D.' cognitive aid for defibrillation[21] (Continue compressions, Oxygen away, All others away, Charging, Hands off, Evaluate, Defibrillate or Disarm). This tool is already widely used in Australia and is used for teaching on accredited ALS courses, though It does not form part of the published ARC recommendations.[23] Coggins[21] showed that with training, the cognitive aid was applied correctly in 92 of 109 defibrillations, and correct cognitive aid use had a shorter median length of peri-shock pause time. Again, no unsafe defibrillation practices were observed.

It is likely that human factors and team skills have a significant impact on how well the anticipatory method works. An observational study in real cardiac arrests reported that long pauses before defibrillation are likely due to human factors during the resuscitation and not due to inherent difficulties with rhythm identification.[24] A randomized manikin study using standard non-anticipatory defibrillation methods showed that 'Hands-on time and time to defibrillation' are significantly worse with ad-hoc teams or when leadership is poor compared to teams with teambuilding and organisation.[25] Finally, anticipatory charging is a new technique. Use of this new unfamiliar technique could have led to underperformance compared to with the standard approach, unless teams had achieved mastery in its use.[26]

Limitations

As a scoping review we have not performed a systematic synthesis of research findings. We did not systematically address the quality of evidence identified or potential bias. We have identified the key available evidence, gaps in the literature and drawn narrative conclusions.

We did not specifically look at:

- New defibrillator technologies that filter the effect of movement during chest compression. The aim of this technology is to show the 'underlying' cardiac arrest rhythm to allow manual interpretation during ongoing compressions without the need for a pause to assess the heart rhythm. If used, this technology could would remove the need to pause for a rhythm check. So far, few centres use these technologies and the outcome benefit of this technology is uncertain.[27–29]
- Modern defibrillators charge very rapidly (most commercially available defibrillators will charge to 150J in manual mode within 3 s on full battery charge).[30,31] In current usual practice, if chest compressions are given during charging only, this could lead to time for very few chest compressions to be delivered, which may not be of any benefit. The human factors and safety aspects of starting compressions and re-assuming a safe position for shock delivery in an attempted 3 s window may result in unnecessary delays or safety concerns. Compressing for a fixed period (e.g. 15 or 30 s) prior to shock delivery would remove any issues caused by the time taken for the defibrillator to charge.
- Anticipatory charging may result in earlier defibrillation of shockable rhythms, as the time from identification of shockable rhythm to shock delivery is reduced, though no data were identified to address this specifically.

Conclusions

Anticipatory manual defibrillator charging appears to be feasible in the clinical setting. Anticipatory defibrillator charging can reduce the overall chest compression pause duration, but may result in longer pre- and peri-shock pause duration.

New technologies may remove the need for pausing chest compressions for rhythm analysis.

The impact of anticipatory manual defibrillator charging on clinical outcomes is uncertain. Future studies of anticipatory charging should focus on clinical outcomes.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of competing interest

QO None declared.

SM None declared.

CD Defibrillation domain lead, ILCOR. Trustee, RCUK.

PM Chair of Australian Resuscitation Council.

JS Chair of ILCOR ALS Task Force. Chair of the European Resuscitation Council ALS Science Committee. Executive committee, RCUK.

Acknowledgments

The authors are grateful to Helen Pullen, Information Specialist at the University Hospitals Bristol Library, for assistance in development of the search strategy.

The authors are grateful to the ILCOR ALS Task force for their collaboration.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.resplu.2020.100004.

References

1. Neumar RW, Otto CW, Link MS, et al. 2010 American heart association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care Part 8: adult advanced cardiovascular life support. *Circulation.* 2010;122:S729–S767. https://doi.org/10.1161/CIRCULATIONAHA.110.970988.
2. Link Mark S, Berkow Lauren C, Kudenchuk Peter J, et al. 2015 American heart association guidelines update for cardiopulmonary resuscitation and emergency cardiovascular care Part 7: adult advanced cardiovascular life support. *Circulation.* 2015;132:S444–S464. https://doi.org/10.1161/CIR.0000000000000261.
3. Deakin CD, Nolan JP, Soar J, et al. European resuscitation council guidelines for resuscitation 2010 section 4. Adult advanced life support. *Resuscitation.* 2010;81: 1305–1352. https://doi.org/10.1016/j.resuscitation.2010.08.017.
4. Soar J, Nolan JP, Böttiger BW, et al. European resuscitation council guidelines for resuscitation 2015: section 3. Adult advanced life support. *Resuscitation.* 2015;95: 100–147. https://doi.org/10.1016/j.resuscitation.2015.07.016.
5. International Liaison Committee on Resuscitation. *ILCOR- Continuous Evidence Evaluation - Task Force Evidence Reviews Guidance Document V 1.0 SAC Approved 5 August 2019.* 2019.
6. Haywood K, Whitehead L, Nadkarni VM, et al. COSCA (Core outcome Set for cardiac arrest) in Adults: an advisory statement from the international Liaison committee on resuscitation. *Resuscitation.* 2018;127:147–163. https://doi.org/10.1016/j.resuscitation.2018.03.022.
7. Haywood K, Whitehead L, Nadkarni VM, et al. COSCA (Core outcome Set for cardiac arrest) in Adults: an advisory statement from the international Liaison committee on resuscitation. *Circulation.* 2018;137:e783–801. https://doi.org/10.1161/CIR.0000000000000562.
8. Tricco AC, Lillie E, Zarin W, et al. PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. *Ann Intern Med.* 2018;169:467. https://doi.org/10.7326/M18-0850.
9. Arksey H, O'Malley L. Scoping studies: towards a methodological framework. *Int J Soc Res Methodol.* 2005;8:19–32. https://doi.org/10.1080/1364557032000119616.
10. Healthcare databases advanced search - search strategy 2019. https://hdas.nice.org.uk/. Accessed October 7, 2019.
11. Godin K, Stapleton J, Kirkpatrick SI, Hanning RM, Leatherdale ST. Applying systematic review search methods to the grey literature: a case study examining guidelines for school-based breakfast programs in Canada. *Syst Rev.* 2015;4. https://doi.org/10.1186/s13643-015-0125-0.
12. Mahood Q, Van Eerd D, Irvin E. Searching for grey literature for systematic reviews: challenges and benefits: MAHOOD *et al. Res Synth Methods.* 2014;5:221–234. https://doi.org/10.1002/jrsm.1106.
13. Paez A. Gray literature: an important resource in systematic reviews: PAEZ. *J Evid Base Med.* 2017;10:233–240. https://doi.org/10.1111/jebm.12266.
14. Edelson DP, Robertson-Dick BJ, Yuen TC, et al. Safety and efficacy of defibrillator charging during ongoing chest compressions: a multicenter study. *Resuscitation.* 2010;81:1521–1526. https://doi.org/10.1016/j.resuscitation.2010.07.014.
15. Hansen LK, Folkestad L, Brabrand M. Defibrillator charging before rhythm analysis significantly reduces hands-off time during resuscitation: a simulation study. *Am J Emerg Med.* 2013;31:395–400. https://doi.org/10.1016/j.ajem.2012.08.029.
16. Kemper M, Zech A, Lazarovici M, Zwissler B, Prückner S, Meyer O. Defibrillator charging before rhythm analysis causes peri-shock pauses exceeding guideline recommended maximum 5 s. *Anaesthesist.* 2019;68:546–554. https://doi.org/10.1007/s00101-019-0623-x.
17. Koch Hansen L, Mohammed A, Pedersen M, et al. The Stop-Only-While-Shocking algorithm reduces hands-off time by 17% during cardiopulmonary resuscitation - a simulation study. *Eur J Emerg Med.* 2016;23:413–417. https://doi.org/10.1097/MEJ.0000000000000282.
18. Cheskes S, Common MR, Byers PA, Zhan C, Morrison LJ. Compressions during defibrillator charging shortens shock pause duration and improves chest compression fraction during shockable out of hospital cardiac arrest. *Resuscitation.* 2014;85: 1007–1011. https://doi.org/10.1016/j.resuscitation.2014.05.001.
19. Cheskes S, Schmicker RH, Christenson J, et al. Peri-shock pause: an independent predictor of survival from out-of-hospital shockable cardiac arrest. *Circulation.* 2011; 124:58–66. https://doi.org/10.1161/CIRCULATIONAHA.110.010736.
20. Edelson DP, Abella BS, Kramer-Johansen J, et al. Effects of compression depth and pre-shock pauses predict defibrillation failure during cardiac arrest. *Resuscitation.* 2006;71:137–145. https://doi.org/10.1016/j.resuscitation.2006.04.008.
21. Coggins A, Nottingham C, Chin M, et al. A prospective evaluation of the "C.O.A.C.H.E.D." cognitive aid for emergency defibrillation. *Australas Emerg Care.* 2018;21:81–86. https://doi.org/10.1016/j.auec.2018.08.002.
22. Iversen BN, Alstrup K, Faurby R, Christensen S, Kirkegaard H. Introducing pre-charge in the pre-hospital setting: a feasibility study. *Acta Anaesthesiol Scand.* 2019;63.
23. Australian Resuscitation Council. ANZCOR guideline 11.4 - electrical therapy for adult advanced life support. https://resus.org.au/guidelines/; 2016. Accessed December 11, 2019.
24. Abella BS, Kim S, Edelson DP, et al. Difficulty of cardiac arrest rhythm identification does not correlate with length of chest compression pause before defibrillation. *Crit Care Med.* 2006;34:S427–S431. https://doi.org/10.1097/01.CCM.0000246757.15898.13.
25. Hunziker S, Tschan F, Semmer NK, et al. Hands-on time during cardiopulmonary resuscitation is affected by the process of teambuilding: a prospective randomised simulator-based trial. *BMC Emerg Med.* 2009;9:3. https://doi.org/10.1186/1471-227X-9-3.
26. Cheng A, Nadkarni VM, Mancini MB, et al. Resuscitation education science: educational strategies to improve outcomes from cardiac arrest: a scientific statement from the American heart association. *Circulation.* 2018;138:e82–122. https://doi.org/10.1161/CIR.0000000000000583.
27. Ruiz de Gauna S, Irusta U, Ruiz J, Ayala U, Aramendi E, Eftestøl T. Rhythm analysis during cardiopulmonary resuscitation: past, present, and future. *BioMed Res Int.* 2014;2014:386010.
28. See-thru CPR - Core technologies - ZOLL medical UK. n.d. https://www.zoll.com/uk/core-technologies/cpr/see-thru-cpr. Accessed January 3, 2020
29. Kuzovlev A, Mancini MB, Avis S, et al. *Olasveengen TM -on Behalf of the International Liaison Committee on Resuscitation Basic Life Support Task Force. Analysis of Rhythm during Chest Compression during Cardiac Arrest in Adults Consensus on Science with Treatment Recommendations [Internet] Brussels, Belgium: International Liaison Committee on Resuscitation (ILCOR) Basic Life Support Task Force.* 2019.
30. Philips - HeartStart XL+ defibrillator/monitor. Philips. n.d. https://www.philips.co.uk/healthcare/product/HCNOCTN88/heartstart-xl-plus-defibrillator-monitor. Accessed December 31, 2019
31. *Cardiolife TEC-8300.* Nihon Kohden Europe; 2017. https://eu.nihonkohden.com/en/products/cardiolife-tec8300.html. Accessed December 31, 2019.